Measurement of the direct photon cross section in proton-proton collisions at $\sqrt{s}$ = 200 GeV with PHENIX

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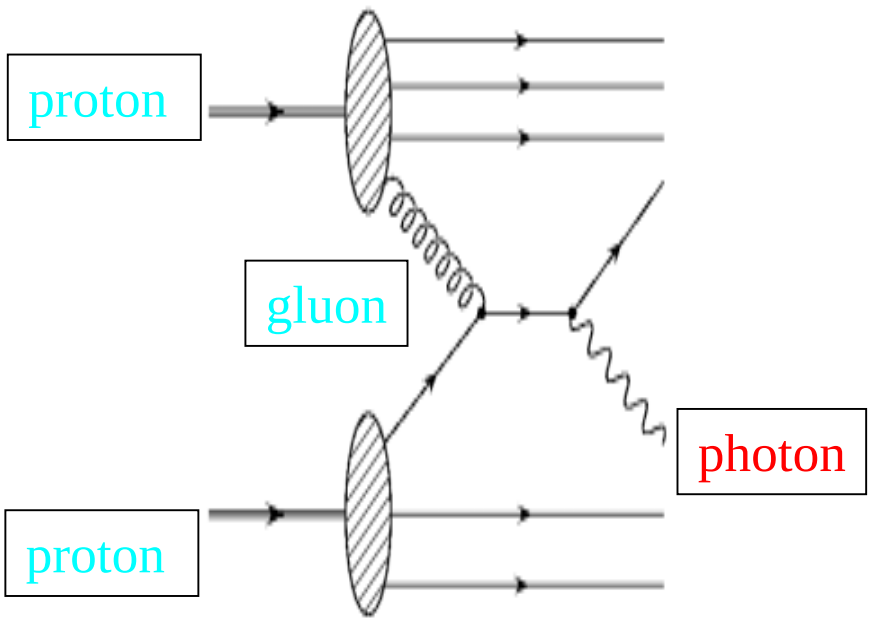
Outline

1. Physics Motivation
2. RHIC-PHENIX
3. Method of photon identification
4. Isolation-cut method
    1. Isolation-cut
    2. Reconstructed π^0 and η
    3. Evaluate fake photon from π^0 and η
5. Direct photon yield
6. Summary

Physics Motivation

Quark-Gluon Compton Scattering

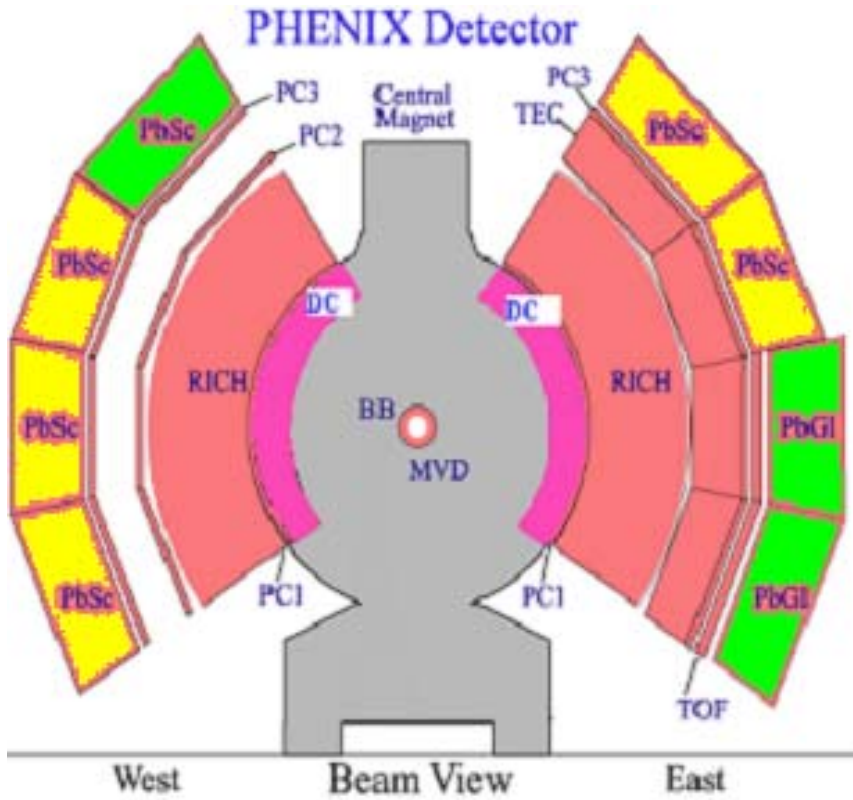


- Measurement of the g(x) (gluon distribution function)
- A test of pQCD

- First step towards the $\Delta g(x)$ (polarized gluon distribution function) measurement in polarized p+p collisions
- Provide a reference for photon measurement in Au+Au collisions

RHIC - PHENIX

- **RHIC – run 2002 pp run**
  - Integrated luminosity 0.15pb^{-1}
    - Vertex cut +-30cm
    - 1671M events
- **EMCalorimeter (EMCal)**
  - 2 Arm $\times$ 4 sectors
    - Lead Scintillator (PbSc) : 6 sectors, size of towers 5.25$\times$5.25 cm^2
    - Lead Glass (PbGl) : 2 sectors, size of towers 4.0$\times$4.0 cm^2
  - $|\eta|<0.38$ $\phi = 180°$
  - Distance from vertex : $\sim$5m
- **Analysis**
  - 5 PbSc sectors are used as a fiducial volume.
  - 16 towerds from edge are removed
  - PC3 are used to remove the charged particles.



Method of photon identification

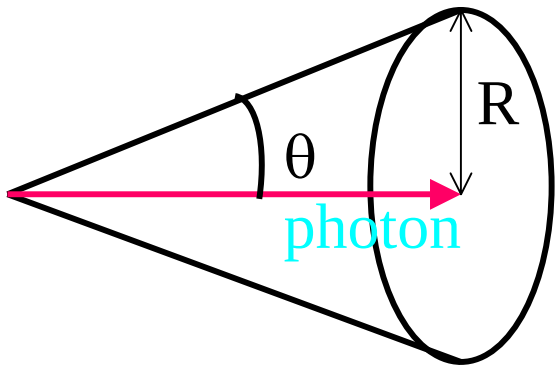
- Isolation-cut method – isolation-cut + π^0 and η reconstruction
  - Remove photons which don't satisfy the "isolation-cut condition"
  - Reconstruct π^0 and η after the isolation-cut and remove these photons
  - Evaluate "fake" single photons from the π^0 and η decay using a Monte Carlo simulation and subtract these photons
- No isolation-cut method - π^0 reconstruction only
  - Reconstruct π^0 and remove these photons
  - Evaluate "fake" single photon from π^0 decays using a Monte Carlo simulation
  - Evaluate photon from η decays assuming that η /π^0 ratio is 0.2 ± 0.05
  - Subtract these photons

Isolation-cut method

- Calculate following valuables :
  - nR5 = “all EMCal energy deposit within θ<0.5 rad from the photon”
  - cR5 = “sum of all track momentum within θ<0.5 rad from the photon”
- Isolation cut condition:

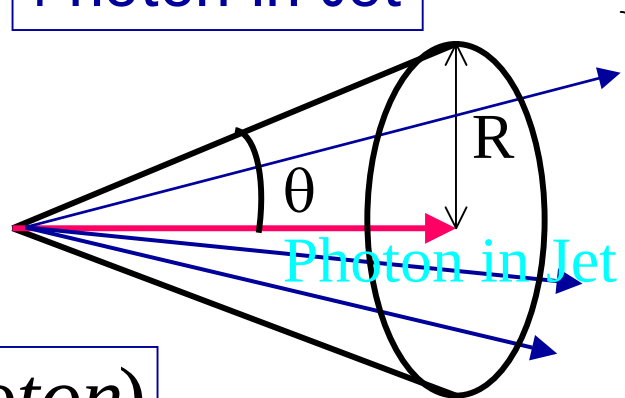
$$nR5 + cR5 < 0.1 \times pT(photon)$$

Direct photon



Single photon

Photon in Jet



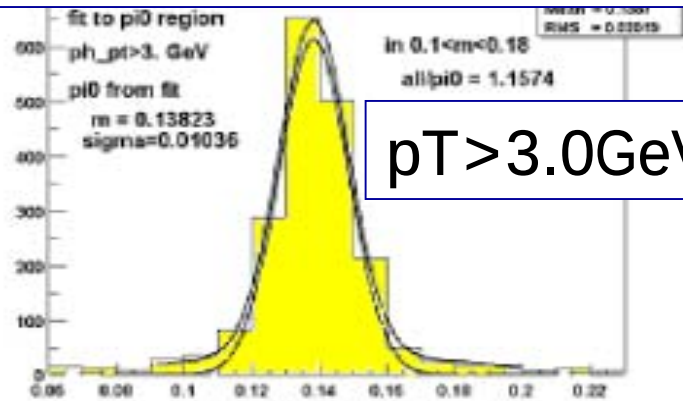
Photons and charged particles

Isolation cut

Reconstruct π^0 and η

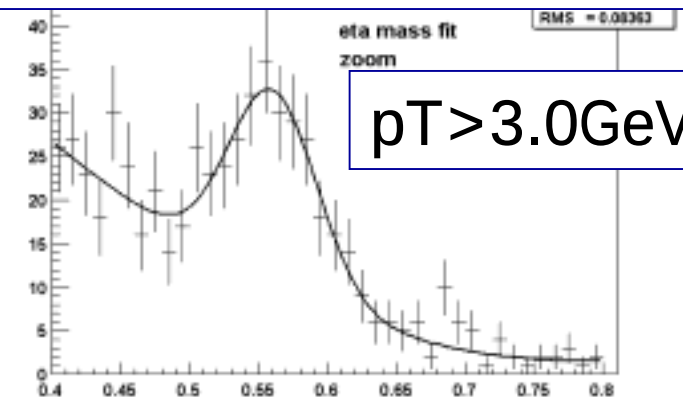
- The background under pi0 sample ($100MeV<M_{\gamma\gamma}<180MeV$) is evaluated as 16%.
- The background under eta sample ($480MeV<M_{\gamma\gamma}<620MeV$). is evaluated as 90%.
- The background fraction is used to correct for reconstructed π^0 and η yield.

π^0 invariant mass spectrum



pT>3.0GeV/c

η invariant mass spectrum

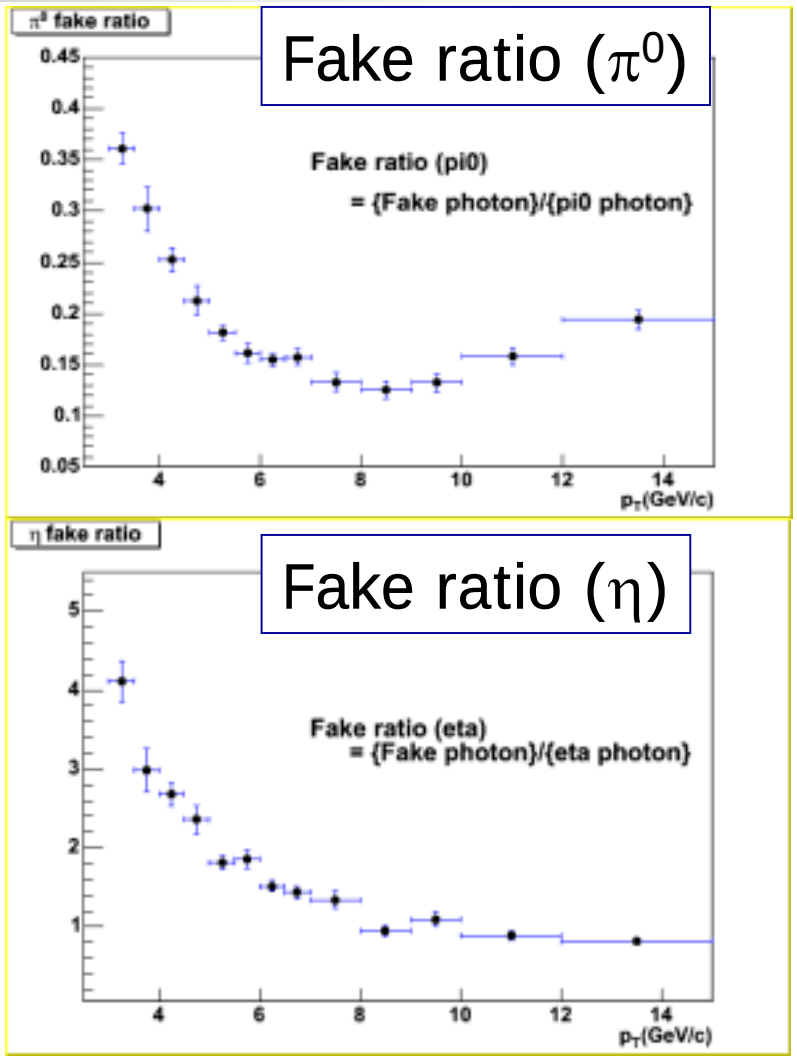


pT>3.0GeV/c

Single photon from π^0 and η decay

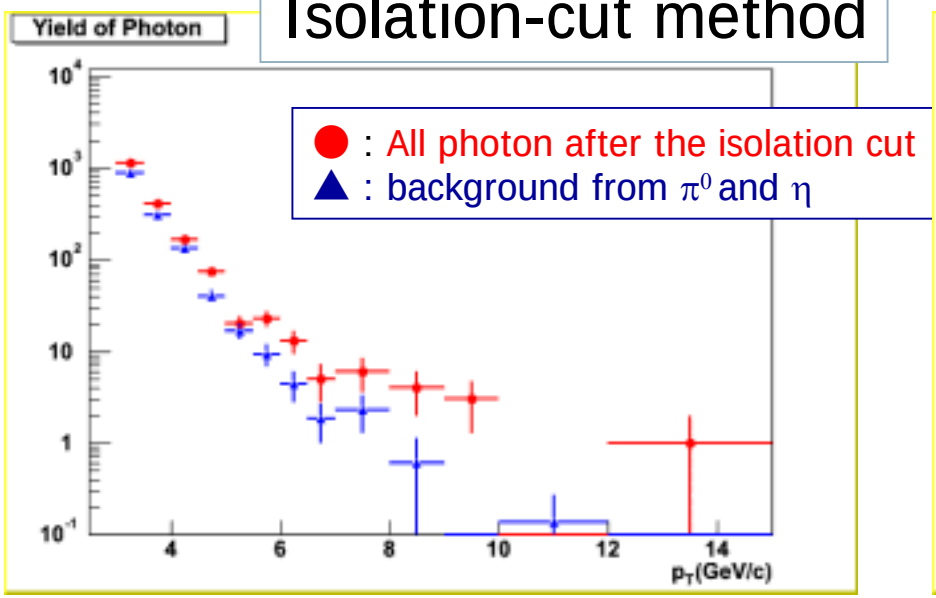
- Using the Monte Carlo event generator and GEANT detector simulation program.
- Define the fake ratio

  {fake photon}/{$\pi^0(\eta)$photon}
- " $\pi^0\,(\eta)$ photon" : photons whose other photon from the same parent $\pi^0\,(\eta)$ is accepted in the fiducial.
- "Fake photon" : photons whose other photon from the same parent $\pi^0\,(\eta)$ is NOT accepted in the fiducial.

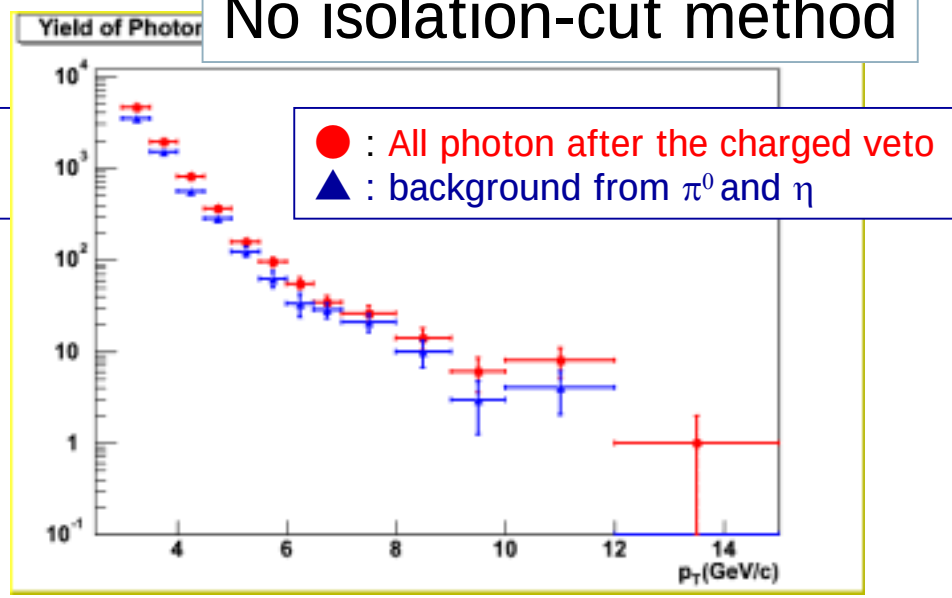


Direct photon yield

Isolation-cut method

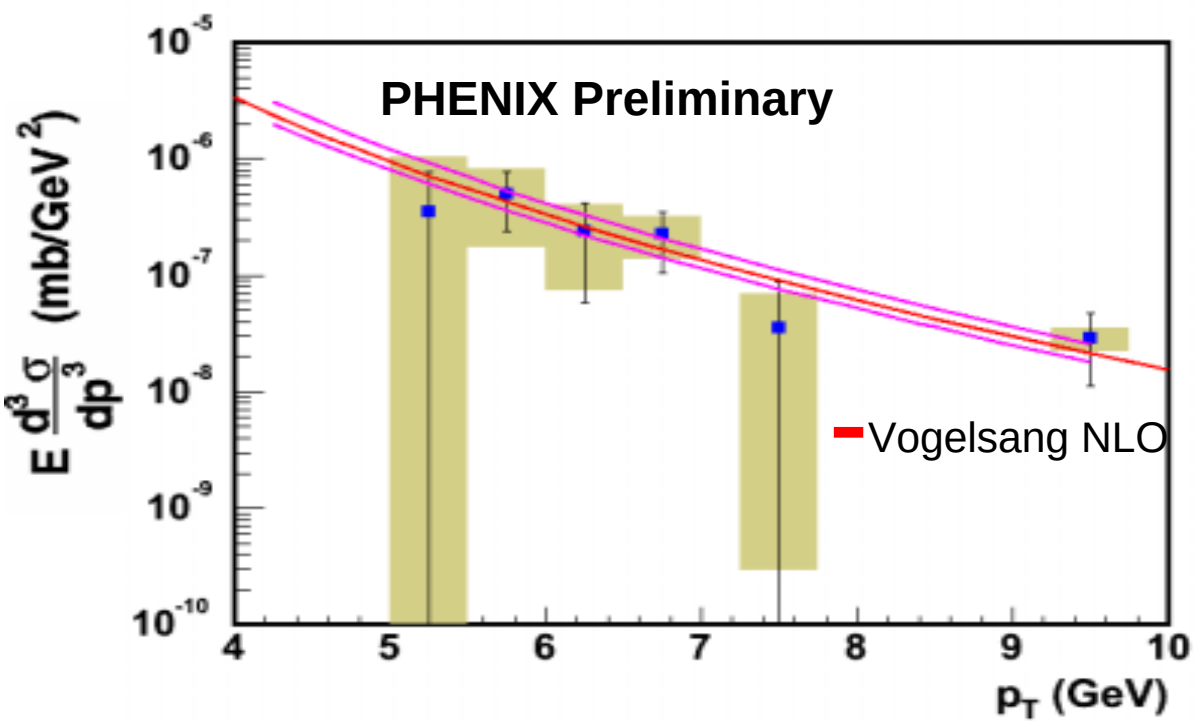


No isolation-cut method



There is significant difference between the all photon yield and background from π^0 and η .

PHENIX Preliminary result



Vogelsang calculation: different scale factors (0.5,**1.0**,2.0), using CTEQ6 gluon pdf: *JHEP 9903 (1999) 025/ private communication*

Summary

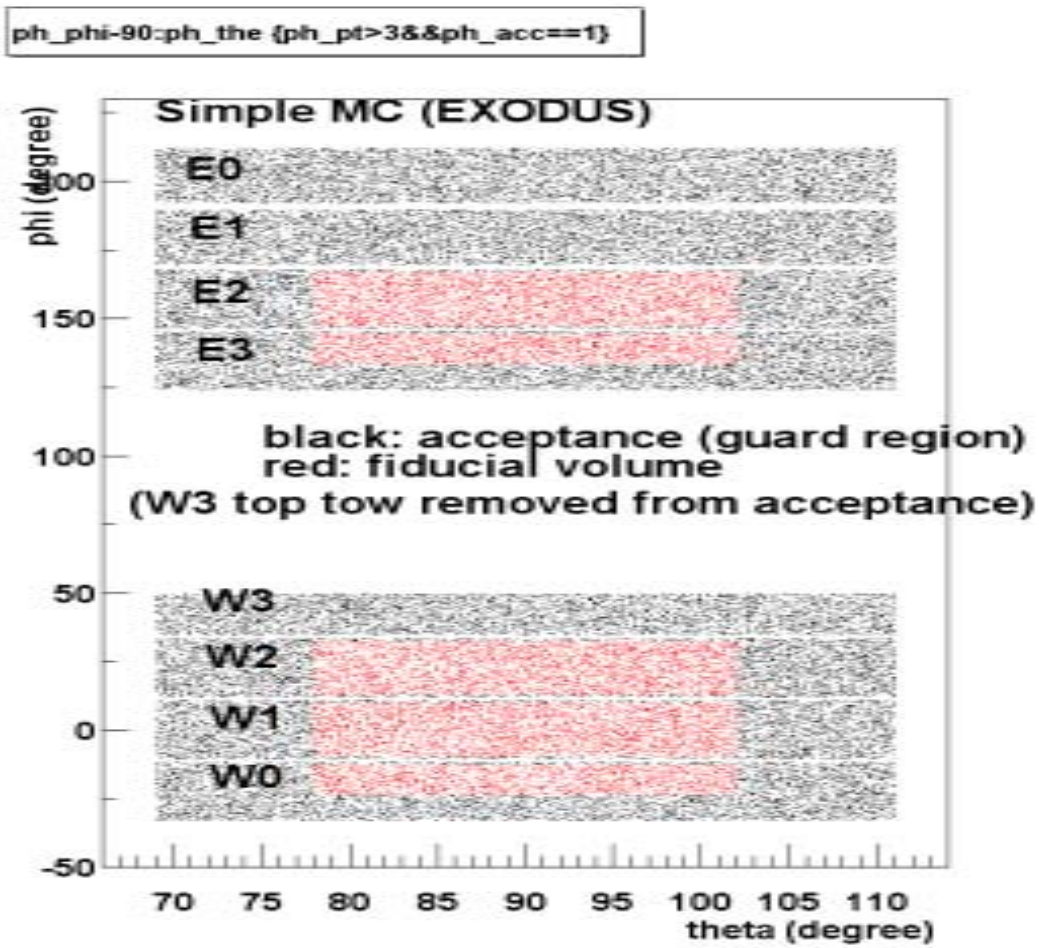
- I investigated direct photon yield in proton-proton collisions in Run2002 at $\sqrt{s}$ = 200GeV.
- Two different methods are used, one is the isolation-cut method and another one is the no isolation-cut method.
- π^0 and η are reconstructed and evaluated fake ratio from them by Monte Carlo event generator and GEANT detector simulation to subtract background from π^0 and η decay.
- I found photon yield much bigger than π^0 and η in both methods, which indicates existence of direct photon.
- We have collected data with an integrated luminosity of 0.35pb^{-1} in the Run2003. Now Run2003 data analysis is started, and will provide more statistical result.

Backup slide (1) Isolation-cut method

- Calculate following values:
  - N_{all} : Number of all photon in the fiducial volume after the isolation cut
  - $N_{ph\_\pi 0}$: Number of photon from π^0 decays
  - N_{ph_η} : Number of photon from η decays
  - $N_{ph\_\pi 0\_reco}$: Number of photon from reconstructed π^0
  - $N_{ph\_\eta\_reco}$: Number of photon from reconstructed η
  - $R_{fake\_\pi 0}$: ratio of fake single photon from π^0 decays
  - R_{fake_η} : ratio of fake single photon from η decays
  - N_{signal} : Number of direct photon candidates

$$
\begin{aligned}
N_{signal} &= N_{all} - N_{ph\_\pi 0} - N_{ph\_\eta} \\
&= N_{all} - (1 + R_{fake\_\pi 0}) N_{ph\_\pi 0\_reco} \\
&\quad - (1 + R_{fake\_\eta}) N_{ph\_\eta\_reco}
\end{aligned}
$$

Backup slide (2) Fiducial cut



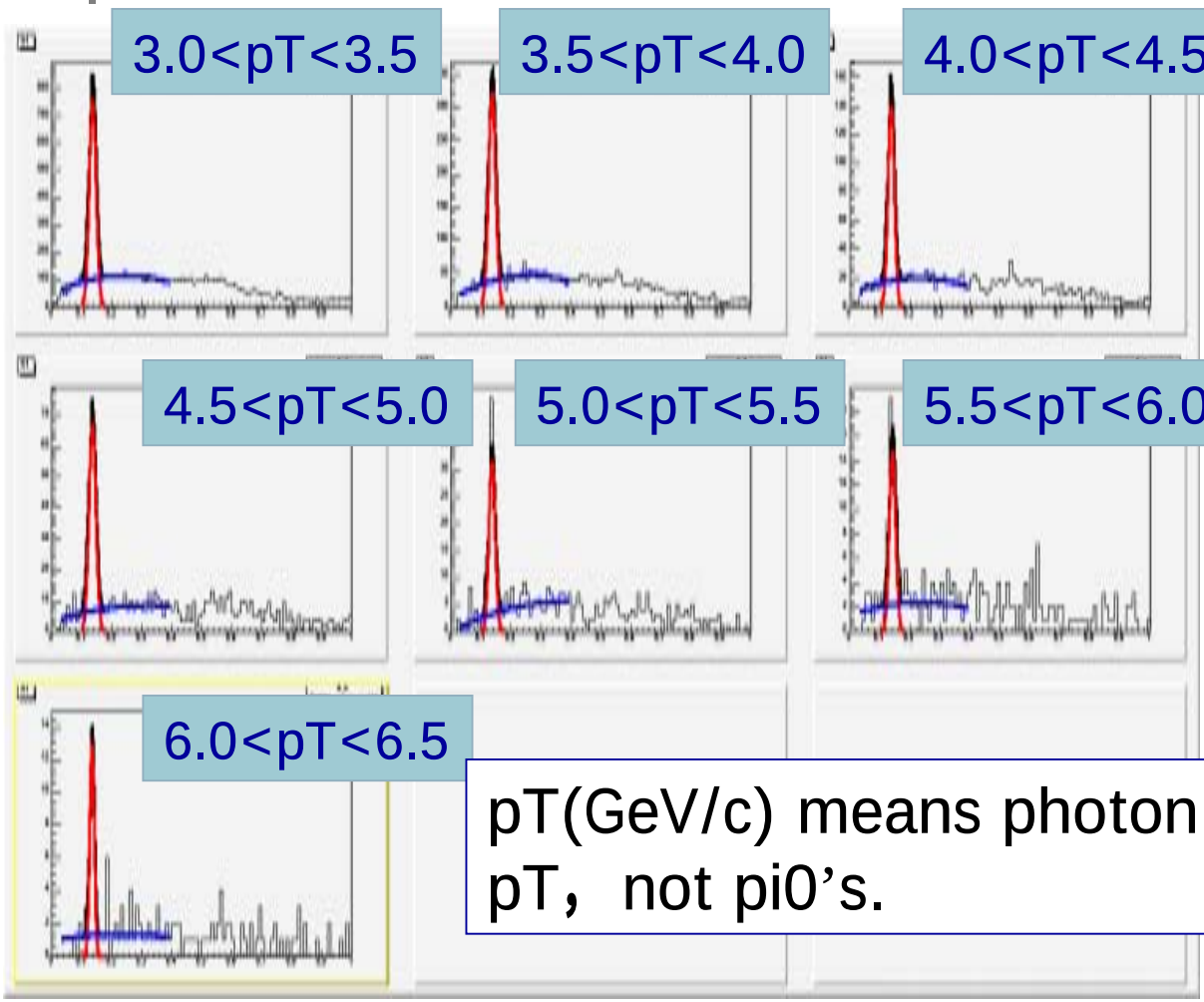
- Define the fiducial volume in EMCal :
  - 16 EMCalorimeter towers from the edge are removed.
  - 5 sectors (Lead Scintillator) are used.
- All EMCal sectors are used for the isolation-cut and reconstruction of π^0 and η .

Backup slide (3) No isolation-cut method

- η reconstruction and "fake" evaluation cannot be done
- Calculate following values:
  - N_{all} : Number of all photon in the fiducial volume after the charged veto
  - $N_{ph\_\pi 0}$: Number of photon from π^0 decays
  - N_{ph_η} : Number of photon from η decays
  - $N_{ph\_\pi 0\_reco}$: Number of photon from reconstructed π^0
  - $R_{fake\_\pi 0}$: ratio of fake single photon from π^0 decays
  - $R_{\eta/\pi 0}$: η/π^0 ratio
  - N_{signal} : Number of direct photon candidates

$$
\begin{aligned}
N_{signal} &= N_{all} - N_{ph\_\pi 0} - N_{ph\_\eta} \\
&= N_{all} - (1 + R_{fake\_\pi 0}) N_{ph\_\pi 0\_reco} \\
&\quad - (1 + R_{fake\_\pi 0}) R_{\eta/\pi 0} N_{ph\_\pi 0\_reco} \\
&\because N_{ph\_\eta} = (1 + R_{fake\_\pi 0}) R_{\eta/\pi 0} N_{ph\_\pi 0\_reco}
\end{aligned}
$$

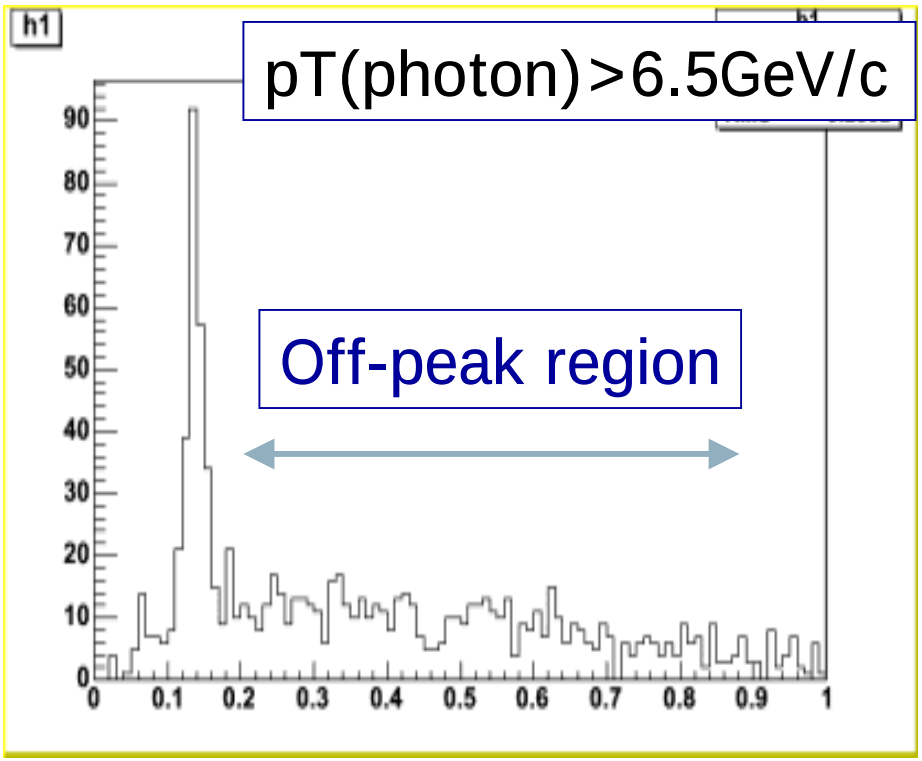
Backup slide (4) Reconstruct π^0



- π^0 invariant mass spectrum is fitted using the function as gauss+polynomial.
- Photon from reconstructed π^0 is obtained after background (polynomial curve) subtraction.

pT(GeV/c) means photon's pT, not pi0's.

Backup slide (5) Reconstruct π^0 at high pT



- We cannot fit at pT>6.5GeV/c, therefore we estimated probability of background using off-peak region.
- Probability of background to signal ~ 38%

Backup slide (6) Remove the charged particles

- This plot shows distance between charged tracks and clusters in EMCal.
- We apply the following cut :
  - |dz|>8.5cm
  - |dphi|>0.015 rad